Notes

I. Introduction

10 CFR Part 835, *Occupational Radiation Protection*, includes provisions for exposure to ionizing radiation from DOE activities, which includes exposures from accelerator operations.

II. *DOE* Guidance

DOE G441.1-5, *Radiation-Generating Devices Guide,* provides guidance on DOE's expectations for controlling exposure from accelerators (see section 4.3.2.1). The IG refers to applicable ANSI standards and DOE O 420.2, *Safety of Accelerator Facilities.*

Article 364 of DOE-STD-1098-99, *Radiological Control*, provides similar guidance, and includes guidance to use the *Health Physics Manual of Good Practices for Accelerator Facilities*, SLAC-327, in meeting occupational radiation protection requirements for accelerators.

DOE HDBK-1108-97*, Radiological Safety Training for Accelerator Facilities*, provides guidance on DOE's expectations for radiation safety training for individuals using accelerators.

III. General characteristics of accelerators

Accelerators are devices that increase the speed and thus the energy of charged particles.

A. Accelerator energy

Accelerators are normally rated by the maximum energy to which the particles are accelerated.

The energy imparted to the charged particles is determined by the potential difference measured in volts (V) in the electrical field. At all but the smallest accelerators, the acceleration is accomplished by directing the charged particles repeatedly through regions containing radiofrequency electromagnetic fields.

Notes

One electron volt (eV) is the energy gained by an electron accelerated through an electric potential of 1 volt.

An electron accelerated across a gap by means of a 10,000 volt, or 10 kilovolt (kV), potential difference is said to have gained 10 kilo electron volts (10 keV) of energy after crossing the gap.

Other energy units commonly encountered at accelerators are: MeV (1 million, or 10^6 electron volts), GeV (1 billion, or 10^9 electron volts), and TeV (1 trillion, or 10^{12} electron volts). These units of energy are commonly used not only for electrons, but for all charged particles.

B. Types of particles accelerated

Particles accelerated include:

- Electrons
- Protons
- Nuclei of various elements

C. Types of accelerators

The accelerated charged particle may move in either a linear (straight line) or in a circular (curved) path as the result of moving perpendicular to a magnetic field; these are the two basic types of accelerators.

1. Linear accelerators

   Straight-line accelerators suffer from the disadvantage that the finite length of flight path limits the particle energies that can be achieved.

Notes

Linear accelerators include:

- Van de Graaffs
- Cockcrott-Waltons

2. Circular-path accelerators

   In circular-path accelerators, magnets guide the particle along a spiral path, allowing a single electric field to apply many cycles of acceleration.

   Circular-path accelerators include:

   - Cyclotrons
   - Betatrons
   - Synchrotrons

Until the 1980's, all accelerators used for both physics research and in practical applications, such as in medicine and in materials science operated in a so-called "fixed target" mode. In this mode the accelerated energetic particles are delivered to a target made of some material at rest in the laboratory.

Since that time, research facilities have been constructed in which counter-circulating accelerated beams of particles collide with each other, rather than with targets at rest in the laboratory. The use of accelerated particles in this "colliding beam" mode has been done to take advantage of the fact that the total energy of the colliding particles, including both their kinetic energies and the energy included in their masses at rest, becomes available in the collision process. This condition is not true for fixed target collisions.

Such colliders are not nearly as numerous as other types of accelerators, but represent

Notes

important research facilities in which basic physics research is conducted.

D. Purpose and uses

Accelerators were originally designed to study the structure of matter. Accelerators today are used not only for basic research purposes, but for many other applications as well. Examples include:

- Production of radioisotopes
- Generation of bremsstrahlung for radiography
- Induction of fusion
- Pumping for lasers
- Detoxification of hazardous waste
- Production of synchrotron radiation

E. Facility size/complexity

Small accelerators/facilities usually mean simpler controls, less staff to coordinate, smaller areas to monitor, and fewer points of access to control. However, small accelerators (lower energy) can produce very intense levels of radiation.

As the size and complexity of the installation increases, so does the importance of clear and concise communication channels and a detailed formality of operations.

IV. Radiological concerns

A. Prompt radiation

Prompt radiation results from the accelerator beam or the interaction of the beam with matter only while the accelerator is operating. Prompt radiation components include:

Notes

1. Primary beam

   The primary beam consists of accelerated charged particles prior to any interactions that may decrease the beam's energy or intensity.

   It is the most intense form of radiation present at an accelerator facility and is made inaccessible to personnel through engineered and administrative controls.

2. Secondary beam

   The secondary beam is produced by interaction of the primary beam with matter such as targets or beamline components. The secondary beam may consist of:

   - Electromagnetic radiation
   - Neutrons
   - Charged particles

3. Skyshine

   Skyshine is the term used to describe radiation emerging more or less vertically from a shielded enclosure, which then scatters from air molecules to produce radiation at some distance from the source.

4. Electromagnetic radiation (photons)

   Prompt photons may include those produced by:

   - Bremsstrahlung: Photons emitted through the deceleration of charged particles in the beam
   - Electromagnetic cascades: Multiple photons emitted through initial high-energy interactions

Notes

- Synchrotron radiation: Photons emitted as charged particles are accelerated in a curved path (a dramatically more significant effect for electrons than it is for protons having the same kinetic energy)

- Thermal neutron capture: Photons can be emitted as a result of nuclear reactions in which materials present in the accelerator enclosure absorb thermalized neutrons produced by the accelerated beams.

5. Neutrons

   Neutrons can be produced through nuclear interactions of the primary and secondary beams with matter. They can also be produced by interaction of high energy photons with matter (photonuclear reaction).

   Neutron radiation is a concern within any area where the beam can interact with physical objects.

6. Muons

   Muons are particles that are physically similar to electrons, but are about 200 times heavier.

   Energies in excess of 212 MeV are required to produce muons by means of pair production at electron accelerators. At proton and ion accelerators, muons cannot readily be produced at energies below about 140 MeV since charged pions or kaons, which decay into muons, must first be produced. Due to the short ranges of low energy muons in matter, they are not normally of concern for accelerators of less than 500 MeV kinetic energy.

   Muons travel mainly in the direction of the beam that produced them, with very little deviation from the beam path. They are a

Notes

concern directly downstream of targets and beam dumps.

B. Residual radioactivity (radioactivation)

Radioactivation is the process by which materials become radioactive. It is commonly referred to as "induced radioactivity" or simply "activation." Generally energies above 10 MeV are needed to activate materials.

Activated materials will continue to emit radiation after shutoff of the beam. The length of time depends on the half-life and quantity of the activated element.

1. Contaminated materials versus activated materials

   Contaminated materials are considered to be items with removable surface contamination. Activated materials are considered to be volume contamination, meaning the radioactive materials are dispersed throughout the items.

   Activated materials normally do not present a potential loose contamination hazard except during activities such as:

   - Grinding
   - Burning
   - Machining
   - Handling filters of coolant water

   Activated materials are normally controlled based on the residual external radiation dose rate.

Notes

2. Activated materials

   Materials that may become radioactive include:

   - Any material within the accelerator enclosure
   - Beamline components
   - Air
   - Liquids

   Accelerators used to produce radioisotopes present special problems because of the variety of target materials used, and because the parameters of machine and target are deliberately optimized to produce radioactive materials.

- Beamline components

  Items that intercept a portion of the beam are most likely to be activated. Among those items which have the highest probability for activation are:
  – Targets
  – Beam dumps or stops
  – Collimators and scrapers
  – Septa and other magnets
  – Cavities and beamline

- Air

  Air and other gases in the accelerator enclosure may be activated. Typically, the activation products are short-lived gaseous radionuclides of the elements in the air. Examples are Oxygen-15 from Oxygen-16.

Notes

The two major concerns of air activation products are:
– Worker (delays entry)
– Environmental (releases from enclosures)

- Liquids

  Tritium is frequently produced in water used to cool the target and/or experimental equipment. As this water supply is usually a closed system, the concentration of the tritium in the water will slowly increase.

  Other activated liquids may include:
  – Oil in vacuum pumps
  – Cryogenic fluids

C. Ancillary sources

Accelerators employ devices to either impart energy to particles, or redirect them during the acceleration process. The following devices may emit ionizing radiation while they are operating.

1. Klystrons

   Klystrons provide power to accelerate charged particles. They emit x-rays during operation.

2. Radiofrequency (RF) cavities

   These devices accelerate charged particles using electromagnetic fields. Trace gases within the RF cavity cause photons to be emitted by the accelerated particles.

3. Electrostatic separators/septa

   These devices split a particle beam into two beams using static electric fields. The high voltages associated with these devices cause electrons to accelerate in the vacuum within the beamline. They emit x- or gamma rays.

Notes

V. Radiological and other controls

Controls are used at accelerator facilities to protect personnel from exposure to ionizing radiation and other hazards, which include:

- Electrical
- Mechanical
- Cryogenic
- Nonionizing radiation

The design of an effective safety program incorporates a combination of engineered and administrative controls.

A. Engineered controls

Engineered controls are the primary controls at an accelerator facility.

1. Active engineered controls

Active engineered controls include devices that sense changing conditions and can trigger a safety action. Examples may include:

- Status lights
- Alarms
- Interlocks
- Scram buttons

2. Passive engineered controls

Once installed, passive engineered controls are used to prevent personnel entry or reduce radiation dose and require no further action to

Notes

perform their intended function. Passive engineered controls may include:

- Barriers
- Shielding

B. Administrative controls

Administrative controls require human interaction in order to be effective.

Key administrative controls include:

- Signs/postings
- Search and secure (sweep) procedures
- Controlled access procedures
- Configuration control procedures
- Radiological Work Permits (RWPs)

VI. Monitoring

Monitoring for radiation at accelerators can be complicated. Special techniques and instrumentation may be necessary due to the existence of:

- Mixed radiation fields (photons, protons, neutrons)
- Pulsed beams
- Very high-energy radiation
- High dose rates

Notes

A. Prompt radiation

Measurements of prompt radiation fields are required for occupational and environmental monitoring and for accident dosimetry and calibration of dosimeters, as well as for research purposes. In selecting measurement techniques and instruments, it is important to consider the purpose of the measurement and the radiation field's parameters.

1. Mixed radiation fields

   The complexity of the radiation field and the radiation measurements increase with the energy of the accelerator.

2. Pulsed radiation

   Prompt pulsed radiation must be measured with specialized survey instruments. Ion chambers are typically used and are recommended.

3. Neutrons

   Neutron monitoring is complicated and must be conducted by highly trained individuals with specialized instruments.

B. Environmental monitoring

Environmental sampling/monitoring may include:

- Prompt radiation (neutrons, skyshine, muons)
- Sampling exhausted air from beam housings
- Surface/groundwater (on and off site)
- Monitoring of radiation levels at site boundary (from storage areas)

Notes

C. Personnel monitoring

Simple dosimeters, such as those used in personal dosimetry and simple survey instruments, should be calibrated when possible in radiation fields that are similar to those in which they will be used. To interpret measurements made with these instruments, one must know as much as possible about the radiation field that is being measured.

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Notes

I. Introduction

Self assessment is part of an effective worker health and safety program. As such, there are many requirements related to conducting self assessments and maintaining quality assurance programs, such as those required under 10 CFR 830.120 ,or as part of an effective Integrated Safety Management program. This module focuses on the radiation protection required assessments and audits.

10 CFR Part 835, *Occupational Radiation Protection*, requires, in 10 CFR 835.102, that internal audits of the Radiation Protection Program be conducted at least every 36 months. The audits shall include all radiation protection functional elements.

Section 4.1.4 of DOE G441.1-1, *Management and Administration of Radiation Protection Programs Guide,* provides guidance on meeting the 10 CFR 835 requirement for audits. Section 4.2 of the Guide includes a listing of radiation protection functional elements and associated DOE guidance documents.

Article 134 of DOE-STD-1098-99, *Radiological Control*, provides additional guidance on radiological control assessments.

Notes

II. Types of assessments

It can be extremely damaging if we, as overseers, facility representatives, and assessors, violate the high standards of performance and rules that we are to assess. It is important to understand that we are constantly being monitored and that we must set the example with regard to radiological protection.

The methods used to gather or capture information can detract from the effectiveness of the assessment process.

Assessment techniques can be enhanced through training and practice. These techniques will improve the ability to see, observe, and better understand.

There are two types of assessments: unstructured and structured. "Unstructured" reviews means "not looking for one specific area or thing." "Minimum preparation" method is accomplished through going with workers on routines. These could be described as general assessments.

The more preparation put into the assessment, the more effective it is, no matter what type of assessment is conducted.

The second type of assessment is "structured," which involves looking specifically at one issue and reviewing it from every angle.

Two traditional methods within the structured inspection are the vertical and horizontal review.

Vertical review is the assessment of a narrow subject area in great detail, for example, assessing the Radiological Control Organization from top to bottom.

Notes

Horizontal review is the assessment of a broad range of related subjects in generally less detail, for example, assessment of radiological protection across all organizations at a nuclear facility.

III. Assessment guidance

A. Documents

IMPORTANT: Put the burden of producing documents on the site. If the site personnel state that it is not appropriate that they comply, they must provide DOE with written support for that position.

The DOE and site basic documents an assessor should have for radiological compliance include (determine the extent of applicability and site commitments to adhere to the documents):

- 10 CFR Part 835
- Site Radiation Protection Program
- DOE-STD-1098-99, *Radiological Control*
- Other applicable federal regulations
- Applicable DOE orders
- State regulations
- DOE Implementation Guides
- Site DOE contract
- Site commitments (corrective actions, DNFSB recommendation responses)
- Site reports (deficiency, occurrence)
- Site-Specific RadCon Manual

Notes

- Approved exemptions

- Peer group/industry group standards/recommendations
  – DOE standards
  – ANSI standards
  – NRC Regulatory Guides

B. Compliance issues

1. Compliance is only the tip of the iceberg.

2. What are the issues?

   - What happened?

   - Why did it happen?

   - Will corrective action prevent recurrence?

   - How can we ensure it will not happen again?

3. Determine the degree of consequence of noncompliance effects and ramifications of noncompliance.

4. Procedural compliance is only part of the overall commitment to excellence in radiological control.

   - Acknowledge good practices

     The DOE radiological control policy is that "continuing improvement is essential to excellence in radiological control."

   - Encourage what is good.

5. Need to distinguish between requirements ("shall" statements) and recommendations ("should" statements).

Notes

C. Compliance orders

Compliance orders are issued by the Secretary. They identify a situation that violates, potentially violates, or otherwise is inconsistent with the:

- Atomic Energy Act of 1954 as amended
- Nuclear statutes
- Nuclear Safety Requirements

Compliance orders mandate a remedy or other action, and state the reason for the remedy or other action.

Examine orders and responses to orders for:

- Timelines
- Accuracy
- Completeness (Was the problem solved?)

IV. Assessing radiological performance

A. Internal audits, inspections, reviews, investigations, and self-assessments comprise "assessments" and are part of the numerous checks and balances needed in an effective Radiation Protection Program.

Internal audits of the Radiation Protection Program shall be conducted such that over a three-year period, all functional elements are assessed for program performance, applicability, content, and implementation. These should be performed individuals who are organizationally independent from the organization responsible for developing and implementing the Radiation Protection Program.

Notes

B. DOE-EM-STD-5505-96*; DOE Limited Standard Operations Assessments,* contains very good methodology for performing assessments.

There are three major components of an effective assessment program: management assessments, operational assessments, and quality assurance assessments. For each of these, functional areas are identified that represent specific areas of managerial or technical activity. Within each functional area, performance objectives are defined that represent essential characteristics or conditions of an effective safety program. The criteria associated with each performance objective are intended to serve as guidelines for the assessments.

Notes

Both management and operational assessments are operationally focused and performance-oriented. They deal with the safety culture of the facility, how safely it is being operated, and the condition of its documentation and equipment. The design of the facility and its process systems is presumed, for purposes of the management and operational assessments, to permit safe operation. This is based on the presumption of an appropriate selection and application of design standards by the architect-engineer and the operating contractor, and of appropriate independent reviews by DOE or its predecessor agencies of the design, the construction activities, and the Safety Analysis Report.

The criteria listed do not address every activity that might be relevant to a performance objective. Therefore, meeting all criteria does not necessarily ensure that the performance objective is fully met. Conversely, a specific facility might achieve the performance objective without meeting all criteria.

In part, because of the various ways in which the performance objectives can be met, effective assessments emphasize the performance objectives rather than the criteria. The methods for determining whether a criterion is met are not given. Consequently, considerable expertise and judgment are required to be exercised in conducting the assessments.

Although the quality assurance assessments have a broad perspective, covering the overall quality assurance program of the facility, they are relevant to assessing radiological protection performance.

DOE-STD-1070-94; *DOE Standard Guidelines for Evaluation of Nuclear Facility Training Programs,* provides guidance on evaluating training programs at nuclear facilities.

Notes

C. Radiation Protection Program deficiencies

Managers should encourage the positive view that identifying even minor deficiencies represents an opportunity for further improvement.

Radiological work practices should be continually scrutinized and questioned so that opportunities for improvement can be identified, assessed, and incorporated into the Radiation Protection Program.

The number of deficiencies, alone, does not measure the overall quality of the Radiation Protection Program.

D. Critiques

One assessment method is the critique. An honest review and establishment of facts, which are in chronological order, is necessary to arrive at the truth.

This is a formal process established to obtain pertinent facts following an unusual radiological situation or at the satisfactory conclusion of a new or unusual operation involving radiological controls.

The process should be used to quickly establish facts in chronological order so that the underlying reasons or causes for the success or failure are well understood. Work force participation should be encouraged. Critiques are a management tool and should not be used to "fix blame" or "shoot the messenger." This process complements the *Occurrence Reporting and Processing* of DOE Order 232.1A.

Notes

In developing corrective action plans, managers should address basic underlying reasons for the identified deficiencies or concerns, not just the specific symptoms identified by the reviewer.

E. Radiation Protection Assessment Program

To accurately assess the performance of the Radiation Protection Program, an assessment program should be formalized, created, and implemented.

Elements of a Radiation Protection Assessment Program

F. Radiation Protection Program Performance

The contractor senior site executive should establish, approve, and maintain a radiological performance goals program. The performance goals should be measurable, achievable, auditable, challenging, and meaningful in promoting improvement. Chapter1, part 3 of DOE-STD-1098-99, *Radiological Control*, provides guidance on appropriate radiological goals.

Goals need to be developed primarily by those responsible for performing the work. Forming a Radiological Awareness Committee that includes the active participation of the work force is encouraged.

Radiological performance goals should be reviewed at least annually and revised as appropriate. Normally, more stringent goals should be set annually to reflect the improved radiological performance at the facility. Occasionally, the goals may be made less stringent to accommodate changes in work load or mission.

Notes

G. Performance indicators

To evaluate performance, one needs to be able to measure change. This means dimensions must be identified. One must be able to track, trend, post, paint, count, look at, and assign numbers. What gets measured, gets done.

Notes

I. Introduction

II. Assessments

A. Reasons for conducting assessments include the following:

- Determine regulatory compliance.
- Formally document Radiation Protection Program strengths and weaknesses.
- Investigate a specific incident.
- Document conditions that need a follow-up assessment.

B. Basic elements of a Radiation Protection Program

- Organization and administration
- Personnel training and qualification
- Quality assurance
- ALARA
- Radiological work control
  – Procedures
  – RWPs
- Posting and labeling
- Radioactive material control
  – Source control
  – Release of materials
  – Receipt and transportation

Notes

- Radiation-generating devices
  - Sealed source
  - X-ray machines
- Entry control
- Contamination control
- Instrumentation and alarms
- Monitoring
  - Workplace
  - Effluent
  - Environmental
- Dosimetry
  - External
  - Internal (bioassay)
- Respiratory protection
- Facility-specific features
  - Uranium
  - Plutonium
  - Tritium
  - Accelerators
- Radioactive waste management
- Emergency response
- Records
- Assessments/performance indicators

C. Indications that an assessment is needed

- Exceeding administrative dose control levels or regulatory limits
- Loss of control of radioactive material

Notes

- Unmonitored/excessive release of radioactive material to the environment
- Excessive numbers of skin contamination incidents
- Uptakes of radioactive material by employees
- Excessive numbers of radiological incidents
- Inadequate training
- Ineffective work control systems
- Incomplete or inaccurate radiological surveys
- Incomplete or inaccurate records

III. Preparing for the assessment

To adequately prepare for the assessment:

- Review operating history
- Examine previous assessment reports
- Collect input from person(s) assessed
- Determine applicability of industry issues
- Review policies and procedures
- Assemble regulations and guidance documents
- Prepare an assessment plan

Notes

A. Operating history

Review the operating history. The following documents can be extremely helpful in preparing for the assessment:

- Occurrence reports
- Radiological deficiency reports
- Violations/citations
- Facility design changes

B. Previous assessments

Examine previous assessment reports. Documents that could be helpful are:

- DNFSB Recommendations
- Self-assessments
- Corporate quality assurance reports
- External audits

C. Input from person(s) to be assessed

- Management
- Radiological Control Manager
- Radiological Control Organization's "customers"

D. Industry issues

- Emerging technical issues
- Application of best industry standards to site program

Notes

E. Policies and procedures

- Operating procedures
- Radiological control policies

F. Regulations and guidance documents

- Federal
- State
- Site
- Industry or peer group

G. Assessment plan

- Identify elements to be assessed.
- Generate specific questions and/or standards against which to measure performance.
- Develop record sheet for assessment responses, data, and field notes.
- Allocate time for each assessment activity.
- Intentionally leave unscheduled time.

IV. Conducting the assessment

A. General guidance

Remember the assessment is a positive activity, designed to help those being appraised. Follow the plan, but be flexible.

Include nothing in the assessment findings that is not based on fact, requirement, or commitment. If in doubt, leave it out (but raise it, informally as a matter deserving a closer look).

Notes

Share the findings with the point(s) of contact each day. There should be no surprises at the daily Radiological Control Manager debriefing or at the final debriefing.

B. Announced versus unannounced assessments

1. Announced assessments are scheduled through a pre-assessment memorandum. The following information should be addressed:

   - Assessment objectives
   - Assessor(s)
   - Assessment duration
   - Request for a site point of contact
   - Any special needs
   - Recommended time and place for pre- and post-assessment conferences

2. Unannounced assessments

   - Used to determine "real" program performance
   - Back-shift, off-hours tours may reveal relaxation in program standards
   - Vary the assessment schedule

   Note: Contact the Radiological Control Manager and line management immediately if there is a serious problem.

Notes

3. Available methods for conducting an assessment include:

   - Document reviews
   - Personnel interviews
   - Field observations

4. Recommended assessment approach (in order)

   - Review upper-tier procedures describing the Radiation Protection Program.
   - Conduct a short (one hour or less) tour of the site/facility.
   - Interview Radiological Control Organization staff and "customers."
   - Conduct detailed and follow-up tours, interviews, and document reviews.

5. Perform document reviews of:

   - Operating procedures
   - Records for:
     – Dosimetry
     – Work control Radiological Work Permit
     – Surveys (contamination, radiation level, air, special)
     – Occurrence, deficiency reports, and critiques
     – Regulatory reports
     – Radioactive effluent reports
     – Training and qualification
     – Instrument calibration and response testing
   - Special studies

Notes

6. Site/facility tour

   - Tour the site/facility, preferably with an experienced individual from the site.

   - Make notes of housekeeping and facility condition. Items to look for include:
     – Leaks, spills
     – Dirt, rust, and clutter
     – Poor equipment maintenance
     – Radiological control posting
     – Radiological Control Technician and Radiological Worker interface
     – Employee morale

7. Conduct interviews with the following:

   - Radiological Control Manager

   - Radiological Control Supervisor(s)

   - Radiological Control Technical Leads

   - Qualified Radiological Control Technicians

   - Radiological Control Organization's "Customers"

   - DOE Site Representatives

   - Facility Manager

   The following are the details:

   - Radiological Control Manager
     – Knowledge of current radiological control regulations, industry standards
     – Identification of program deficiencies and priorities
     – Obstacles to improving program performance

Notes

- Radiological Control Supervisor(s)
  - Level of support given Radiation Protection Program and Radiological Control Manager
  - Identification of program deficiencies and priorities
  - Obstacles to improving program performance

  Note: Compare responses to those from Radiological Control Manager.

- Radiological Control staff members responsible for major technical functional areas.

  Examples of these functional areas include:
  - Organization and administration
  - Personnel training and qualification
  - Quality assurance
  - ALARA
  - Radiological work control
    + Procedures
    + RWPs
  - Posting and labeling
  - Radioactive material control
    + Source control
    + Release of materials
    + Receipt and transportation
  - Radiation-generating devices
    + Sealed source
    + X-ray machines
  - Entry control
  - Contamination control
  - Instrumentation alarms
  - Monitoring
    + Workplace
    + Effluent
    + Environmental
  - Dosimetry
    + External
    + Internal (bioassay)
  - Respiratory protection

Notes

  - Facility-specific features
    + Uranium
    + Plutonium
    + Tritium
    + Accelerators
  - Radioactive waste management
  - Emergency response
  - Records
  - Assessments/performance indicators

  Document their responses to incidents in their technical area.

  Discuss impediments to improving their programs.

- Qualified Radiological Control Technicians
  - The depth and breadth of knowledge of radiation protection
  - Technical issues unique to the site/facility
  - Effectiveness of the working relationship between Radiological Control Technicians and their "customers"

- Radiation Protection Program "customers"
  - Knowledge of fundamental radiation protection concepts and good Radiological Worker practices
  - Working relationship with the Radiological Control Technicians
  - Obvious or hidden problems
  - Poor communications
  - Division of work problems
  - Overall, how the Radiological Control Organization is regarded ("policeman" vs. team member)

Notes

- DOE Representatives
  - If the Radiological Control Organization staff solicits his/her input on technical decisions affecting Radiation Protection Program performance
  - If the relationship is one of mutual respect or adversarial in nature

- Facility Manager
  - Whether the Facility Manager has made a written commitment and is striving to achieve excellence in the Radiation Protection Program
  - His/her perspective on how the Radiation Protection Program should be improved, and the necessary priorities

8. Observe Radiological Workers/Radiological Control Technicians in the workplace

   - Recommendations for observing work include:
     - Dress as the individuals being observed are dressed.
     - Work the same hours they work.
     - Stand away from the immediate work area, but close enough to watch the work proceed.
     - Resist the urge to get involved in the work.
     - Be professional and courteous, but not familiar.

   - Key areas to watch for include:
     - Procedure violations
     - Failure to follow RWP requirements for:
       + Dosimetry
       + Protective clothing
       + Respiratory protection
       + Radiological Control Technician coverage
       + Surveys
       + Special instructions

Notes

  - Poor Radiological Worker practices:
    + Reaching across radiological boundaries
    + Scratching body with gloved hand
    + Inadequate frisking
    + Loitering in a high radiation field
  - Lack of organization or formality in the work process
  - Poor housekeeping, disorderly work area
  - Wasted time and effort due to ineffective work planning
  - Communication problems
  - Poor relationships between Radiological Workers and Radiological Control Technicians

C. Post-assessment actions

At the post-assessment conference, summarize the findings identified during the assessment. This is an opportunity for additional questions about the findings. Any requests for corrective actions, dates, or a need for follow-up assessments can be identified at this time. Thank everyone for cooperation and support during the assessment.

1. Publish assessment findings.

2. Receive site responses, which should include the following:

   - Action items

   - Responsible individuals/groups

   - Action item due dates

3. Accept/reject/modify responses.

4. Develop corrective action tracking list.

5. Publish a periodic action item status report.

Notes

6. Maintain a separate file of open action items.

7. Personally verify the closure of action items.

8. Evaluate the adequacy of actions taken to close open findings:

   - Has root cause been correctly identified and corrected?

   - Are follow-up assessments needed?

D. Follow-up assessments

1. Qualifying conditions

   - Widespread problem
     – Problem occurs at several locations in the same facility or several facilities at the same site.
     – Problem identified by the assessment is only part of a larger, more generic deficiency.

   - Recurring problem: earlier efforts to resolve the problem have been ineffective.

2. Actions

   - Widespread problem
     – Take a longer sample to confirm/refute a widespread problem
     – Look for related problems in the same work unit.

   - Recurring problem
     – Scrutinize root cause analysis.
     – Try a different approach to solving the problem.
     – Solicit outside help. Perhaps others have "lessons learned".

3. Incorporate follow-up assessment information into corrective action tracking system.

Notes

V. Marginal radiological performance

When radiological control performance is less than adequate, strengthen line management's commitment to radiological control by notifying the Radiological Control Organization to obtain their support in improving radiological support.

In cases where the work force does not have the required level of sensitivity for radiological work practices, additional management attention is needed to assure the proper outcome. Line management should be held accountable for implementation of the Radiation Protection Program.

Initial actions should include:

- More direct line supervision in the work space
- Curtailment of work schedules
- Addition of extra radiological control personnel
- Conduct of additional training

Notes

I. Introduction

II. Case studies guidance

Point to remember: If each root cause is not adequately treated/corrected by a corrective action, recurrence of the event or some variation of it is likely.

Review a reconstruction of events from the available data.

A proper investigation report or occurrence report reconstructs the events as they occurred.

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III. Description of occurrence (edited from investigation report)

A. Incident

The layout of the buildings and equipment at this site are included.

Two employees at the Paducah Gaseous Diffusion Plant (PGDP) received skin and clothing contamination from Thorium-234 (^{234}Th) and Protactinium 234m (^{234m}Pa) while disconnecting a used uranium hexafluoride (UF_6) cylinder at the C-337-A building, UF_6 Feed Vaporization Facility, on August 23, 1991.

B. Scenario of events

Starting at shift change, 12 employees, one of them a Health Physics Technician, found contamination on shoes and clothing. The incident was initially identified during routine monitoring of the C-337-A facility by a Health Physics Technician at 0900 (two hours after the shift change). Efforts were initiated by Health Physics to survey the area, identify the source, and control the spread of contamination. Surveys indicated widespread contamination in both radiological and nonradiological areas of C-337 (adjacent to C-337-A) and C-337-A.

At some unspecified time, a critique was conducted by the Assistant Shift Superintendent and all personnel involved in the accident were interviewed.

All personnel who had been in the facility on the day shift were contacted and surveyed. One individual was found to have contaminated shoes and skin contamination on the elbow and was taken to a change house in C-337 for decontamination. Later this employee's personal clothing was also found to be contaminated, and through further investigation it was learned that this contamination occurred in the change house. A thorough survey was conducted in

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the change house, and it was discovered that, in addition to a few articles in the change house itself, two locks and lockers used by Employee No. 1 (who performed the pigtail changes on the previous shift) were contaminated. This employee returned to work at 1830 on August 23, 1991. Surveys of the locker contents indicated contamination on company-issued clothing worn the previous shift. The employee was also found to have skin contamination of 6500 dpm/100 cm^2 on the arm, 4500 dpm/100 cm^2 on the knee, and 2750 dpm/100 cm^2 on each ankle.

A survey of the employee's coworker's (Employee No. 2) locker revealed contaminated items (both company-issued and personal). Personal surveys conducted when Employee No. 2 returned to work showed the presence of skin contamination of 4500 dpm/100 cm^2 on hair, 5000 dpm/100 cm^2 on neck, and 40,000 and 15,000 dpm/100 cm^2 on wrists. Later (2130 hours on August 23 for Employee No. 2, and 1900 hours on August 24 for Employee No. 1) surveys were conducted at the employees' homes. Monitoring of one employee's home found one T-shirt and one pillowcase slightly contaminated. A pair of shoes at the other employee's home was found slightly contaminated. This employee's (No. 2) coveralls had already been sent to the laundry, since it was not recognized they were contaminated. After laundering, significant contamination was still present (up to levels of 250,000 dpm/100 cm^2 at ankles, and lower levels at other places). A survey of the laundry equipment did not indicate any contamination.

Based on statements from the involved employees, they utilized the required personal protective clothing and equipment for the job at the time. The autoclave area is designated as a Contamination Zone. Anti-contamination clothing designated for cylinder changes at the time of the incident consisted of company-issued coveralls (blues), gloves, and shoe scuffs. Operational procedures require the use of a respirator when disconnecting

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pigtails. Surveys conducted as part of this investigation did not show any contamination on the employees' respirators or respirator cartridges.

The actual incident began between the hours of 0130 and 0415 on August 23, 1991, at the PGDP C-337-A Feed Vaporization Facility.

The operators routinely assigned to C-337-A for the period of 1900 hours on August 22, 1991, through 0700 hours on August 23, 1991, were not available due to the illness of one and an alternate work assignment of the other at another facility (C-360). Two operators who are not routinely assigned to the area were then assigned to cover C-337-A. One operator (No. 2) was qualified for operation of the facility while the other (No. 1) was in training for qualification. (This is in compliance with facility Operational Safety Requirements.) Supervisor interaction was minimal, with only one brief visit around the middle of the shift.

The operations in process at the time of the incident were the routine disconnection and removal of emptied UF_6 feed cylinders and subsequent replacement with full cylinders. This operation consists of disconnecting a short length of connecting pipe between the cylinder and the system piping that leads to the diffusion process equipment. This pipe is called a pigtail; it has threaded connections and gaskets on each end. Since pigtails are routinely reused, each cylinder change requires replacement of gaskets on pigtails to minimize the possibility of UF_6 releases during heating and feeding of the UF_6 into the diffusion process. At times these gaskets can be difficult to remove from the pigtail. A special tool is available to assist in the removal of these gaskets; however, difficulty can still be encountered. The pigtails used that night had been used for several feeding cycles, as is normally the case. The exact number of cycles could not be determined.

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There are levels of ^{234}Th and ^{234m}Pa that occur naturally from the decay of ^{238}U present in the cylinder pigtail, pigtail gaskets, and cylinder valves. Approximately one curie each of those two radioisotopes builds up in a cylinder within a few months. These materials are less volatile than UF_6, so they remain as solids at the autoclave temperature, but some small amounts are entrained in the UF leaving the cylinder and small quantities are deposited in the cylinder valve and pigtail as the UF passes through it. These materials are present as removable surface contamination in these components, as well as being present in quantity in the cylinder heels (the material remaining in the cylinder after feeding). No containment of the ends of the pigtail during the gasket removal process was required by procedure. Additionally, the facility-specific training program does not address the specific contamination hazard the cylinder/pigtail change represents.

The operators changed four cylinders on the shift. The cylinder number, autoclave used, and approximate time of change (from logs and recorder data) are shown below:

Cylinder Number	Autoclave Number	Approximate Time
K-438	3 West	0130 08/23/91
K-505	5 West	0320 08/23/91
K-472	1 West	0500 08/23/91*
AC-1090	4 West	0500 08/23/91

*Time is very approximate. Operator statements place the change late in shift.

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There was a portable fan temporarily positioned to cool employees just north of the 5 West autoclave control panel, inside the Contamination Zone. The fan had only been in place a few weeks. It was operating during the shift in question. Apparently no one had questioned the use of this fan in the area prior to the event. Circumstantial evidence places one operator exiting from either the 4 West or 5 West autoclave in the path of this fan while trying to remove a pigtail gasket. The area of highest surface contamination was spread along a line from the fan (located by 5 West autoclave), past the 4 West autoclave to the 3 West autoclave control panel in the direction that the fan blows.

Self-monitoring performed by the employees upon exiting the Contamination Zone where the job was performed was inadequate, in that the employees did not recognize the contamination present on their skin and/or clothing. The employees performed their other duties during the remainder of the shift, thereby spreading this contamination to both radiological and nonradiological areas. This spread of contamination to nonradiological areas through failure to recognize personal contamination at exit monitoring stations caused other personnel to become contaminated when the shift change at 0700 on August 23, 1991, brought new personnel into these areas.

Based on the interview with Employee No. 1, the employee traveled to C-337 around 0400 for a break. Upon exiting the vaporizer Contamination Zone and going to the C-337-A Operation's Monitoring Room, the Bicron frisker was indicating high but not alarming due to high ambient background radiation levels. The employee reset the monitor and remonitored. The employee indicated that the reading was elevated, but was not alarmed this time. The employee stated this was normal since the background in that area is often high.

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At approximately 0600 on August 23, 1991, both operators left C-337-A bound for the C-337 change houses and the C-337 Area Control Room for shift turnover. Both operators stated they used Bicron friskers to check for contamination prior to entering the nonradiological (green) pathway in C-337. Training previously received by each operator for each type of frisking equipment was documented. Employee No. 1 noted that the Berthold hand-and-foot monitor previously used was "not operating properly," so the employee used the Bicron frisker. Neither operator noted any contamination. Employee No. 2 monitored hands and feet only, based on subsequent interviews, which indicated that the employee did not know that a whole-body frisk was required when exiting a radiological area. Based on statements from both employees, they showered, changed into personal clothing, completed the shift turnover activities, and exited the building after monitoring hands and feet at the building exit, as required.

Since some personnel exit monitoring data is regularly recorded, this data was reviewed. The operators passed between the C-337-A Operation's Monitoring Room and the C-337 Area Control Room several times during the shift and should have performed a whole-body frisk for contamination each time. Data for Employee No. 2 was not available, as the employee used a Bicron frisker. (These instruments do not have the added feature of storing monitoring data for later review.) Data for employee No. 1 shows 0414 hours on August 23, 1991, as the first time a monitor station evaluated this operator as contaminated. This station would normally be used when passing from C-337-A to the C-337 nonradiological walkway when going to the maintenance shops and change houses (restrooms, lockers, and showers).

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This same employee was also known to be contaminated at the C-337 building exit on two separate monitors (twice on one, once on the other) when leaving after the shift change approximately 0700 on August 23, 1991. The employee stated that the first monitor alarmed, but that the second monitor did not indicate the contamination.

No monitoring data was found for the second employee, since he did not utilize equipment capable of storing this information.

Personal egress monitoring data from the facility was also reviewed, and individuals from prior shifts were contacted and monitored. An operator who was in the C-337-A area extensively from 0700 to 1830 hours on August 22, 1991, had a new pair of company-issued shoes, which were found to be free of contamination. This operator had left the C-337-A facility at 1830 hours on August 22, 1991. Additionally, routine surveys on August 19, 1991, did not indicate a similar contamination problem. Since no significant contamination problems were identified prior to 1900 hours on August 22, 1991, the investigation focused on the activities from 1900 hours on August 22, 1991, to 0700 hours on August 23, 1991.

Urinalysis, as well as *in vivo* internal dosimetry assessments, was performed on these employees and did not indicate any evidence of internal contamination. Personnel whole-body external radiation dosimeters worn by both employees, although externally contaminated, did not indicate that abnormal doses to ionizing radiation were received.

Skin dose calculations showed less than 0.10 rem for Employee No. 2 and 1.50 rem for Employee No. 1, compared to an annual limit of 50 rem.

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It was noted that in the occurrence report of Reference 2, there had been 26 similar occurrence reports (in 1991) at the facility.

IV. Compensatory measures

Following the detection of contamination, several actions were taken by facility management in order to determine the source and type of contamination, the personnel and areas which may have been contaminated, and actions which could be taken to minimize additional spread of contamination. The following list of significant actions were accomplished after the event:

1. A critique of the incident was conducted, interviewing all individuals involved.

2. All nonradiological areas were decontaminated, and contamination levels within the radiological areas were reduced.

3. Personal protective equipment requirements in C-337-A were upgraded to require full anti-contamination protective clothing within the Contamination Area.

4. A full-time Health Physics Technician was stationed at C-337-A and required to monitor all personnel and equipment leaving the radiological area.

5. The two operators involved in the incident were sent to the Fernald, Ohio (DOE), facility for *in vivo* (whole-body) monitoring.

6. The fan was removed from the facility.

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7. *In vitro* urine bioassay samples were obtained from the individuals involved in the incident, as well as other individuals who were either contaminated on previous shifts or involved in surveying and decontaminating the area.

8. Dosimeters were collected and monitored to assist in determination of radiation dose.

9. A walkdown of all plant boundary control stations was performed by senior management to determine location of substandard boundary control stations.

10. Efforts were initiated to determine other possible sources of Th^{234} and Pa^{234m} at other plant locations.

11. Actions were initiated to reduce the potential for the spread of contamination from the UF_6 cylinder pigtails during disconnection, gasket replacement, and reconnection activities.

12. Surveillance was established by line management of exit monitoring stations.

13. An investigation for an organizational finding was initiated.

14. A news release was issued.

15. A plant announcement was made and a plant bulletin was issued to emphasize the seriousness of the situation and the need for proper monitoring.

16. Complete locker room surveys were performed by Health Physics Technicians.

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17. Meetings with union membership were conducted by union leadership to emphasize the importance of monitoring.

18. A letter, jointly signed by PGDP management and union leadership, was issued to all PGDP employees.

19. A DOE visit from Headquarters (HQ) Health and Safety personnel was conducted. They concluded that the breadth and scope of the organization finding investigation was appropriate.

20. The Portsmouth Gaseous Diffusion Plant was notified of the incident for possible application at its site.

21. Operators involved in the incident were not allowed to work in radiological areas until Radiation Worker retraining had been completed.

22. All fact sheets were put into "operator-required reading" files.

23. Development of a training film to review monitoring requirements and techniques was initiated. Upon completion, review of this film will be mandatory for all employees.

Analysis - Contamination Levels on Gaskets and Pigtails

Sample Number	Nuclide Analyzed	Concentration (dpm)
C-337-A Gaskets (2 gaskets combined for one sample)	^{234}Th and ^{234m}Pa	11,000,000 Beta*
	U activity	156,000 Alpha
C-310 Burp Station Gasket (1 gasket)	^{234}Th and ^{234m}Pa	163,000 Beta
	U activity	140,000 Alpha
C-310 Product Withdrawal Gasket (1 gasket)	^{234}Th and ^{234m}Pa	40,000 Beta
	U activity	1,900 Alpha
C-315 Tails Withdrawal Gasket (2 gaskets)	^{234}Th and ^{234m}Pa	117,000 Beta
	U activity	20,600 Alpha
C-360 Sampling and Transfer Facility Gasket (3 gaskets)	^{234}Th and ^{234m}Pa	1,500,000 Beta
	U activity	78,000 Alpha
SP-8757, Pigtails coupling, feed header end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta*
	U activity	see Note 1 Alpha
SP-8758, Pigtail coupling, cylinder end of pigtail	^{234}Th and ^{234m}Pa	see Note 1 Beta
	U activity	see Note 1 Alpha
SP-8759, Material knocked loose from SP-8757	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	27,000 Alpha
SP-8760, Material knocked loose from SP-8758	^{234}Th and ^{234m}Pa	2,300,000 Beta
	U activity	75,000 Alpha

*Each radionuclide contributes 50 percent to this total activity.

Note 1: Beta/gamma levels were too high to be accurately counted on the spectrometer due to detector dead time (saturation).

Notes

I. Introduction

II. Writing assessment findings

A. Organization of findings

There may be considered to be three categories of assessment findings in order of increasing severity:

- Surface findings (Type I) are usually indicators of underlying issues that may be more significant. Note that a common problem is treating or correcting only the surface issue while ignoring the underlying problem—this results in problem recurrence.

- Substantial findings (Type II) are typically issues that are underlying and more significant. Note that correcting the underlying problem results in solving the problem.

- Organizational findings (Type III) deal with programmatic or global issues. Note that correcting these is very difficult if they involve system, organizational, or institutional problems.

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First, group like, related, or similar findings into a broader issue.

Then, review the overall list of groupings for priority. The bases are:

1. Imminent danger
    - Life Safety Code
    - Personnel Safety
    - Facility Safety
    - Criticality
    - Confined Space
    - Traps
2. Not imminent, but potential danger
    - Environmental monitoring, e.g., inadequate stack monitors
3. Violations of regulations, laws, orders
4. Areas where adverse public opinion may reside
5. Performance and effectiveness issues
    - Usually a large number of findings fall into this category, which captures effectiveness and quality issues.

Finally, establish what is most important and what should be brought to the attention of the senior DOE and contractor management.

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B. Writing of findings

When it has been established what issues will be brought to site management, review techniques for writing about the findings:

There is an established style or method often used in industry for writing findings. It consists of the following three steps:

1. List the requirement

2. State what was observed (different from requirement)

3. State the concern

III. Presentation of Findings

After findings are prepared in written form, it is important that they be presented properly. Skills for presenting findings are directly related to the techniques used for writing findings.

Some rules to keep in mind when presenting findings are listed below.

- Identify the assessment team leader and members, and their organizational affiliation.

- Explain the reason for the assessment.

- NEVER, NEVER read the findings in a close-out. Most senior management can read as well as the presenter.

- Present the most significant findings first.

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- Be prepared to present additional information to support the finding. In most cases, there is much more material in the file than is appropriate to be included in the write-up. Be prepared to use that material to support the finding.

- In some cases, this is the time to cover material in the report that was not written for public consumption.

- It may be appropriate to discuss other material such as related findings from previous reports or audits.

- Maintain proper perspective by including both positive and negative findings.

- Start with the positive findings, then make a clear, shift to the negative findings or concerns.

- Explain the concerns/findings enough so that senior management will understand the issue.

- Thank the site contact person and most senior manager(s) for help and hospitality extended during the assessment.

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I. Introduction

II. Compliance-based versus performance-based evaluations

A. Compliance-based audits

A compliance-based audit is a comparison of the requirements laws, rules, orders, guidance, policies, procedures, and other documentation with site practices to confirm implementation of the specific requirements. For example, determining whether bioassay samples were collected in accordance with site procedure requirements.

B. Performance-based assessments

Assessment is fundamental to the operation of a satisfactory Radiation Protection Program.

A performance-based assessment is a review of how the actual performance of the task is accomplished and assessing whether the intent of the requirement is being met. For example, determining whether bioassay samples were being analyzed for the appropriate isotopes given the workplace environment.

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III. Assessment process

The assessment process is one of the evaluation methods used to determine the status and effectiveness of an overall management system.

With this perspective, the assessment process should be planned and scheduled to accomplish the following:

- Evaluate the effectiveness of program implementation in order to meet compliance requirements
- Provide input for assessment process improvement.

The assessment process consists of four phases:

1. Planning
2. Performance
3. Reporting
4. Response evaluation, follow-up, and close-out

A. Planning

Planning is the key to a successful assessment. It is possible to go immediately to the field to observe, work with, and find out how things are being done. That is one element and approach to the process, but there is a greater advantage to be made with proper planning and preparation.

The most successful assessments start with a checklist. The checklist development is critical to the success of the assessment and serves as a commonly accepted method for documenting what was looked at and what the results were. It also serves as a guide to the person performing

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the assessment and provides objective evidence that an assessment was performed.

In performing the assessment, several types of checklists can be used. The preferred style of a checklist is the question-and-answer variety. With this kind of checklist, the assessor has to write-in an evaluation of the answer to each question and any qualifying remarks. The question-and-answer format is more difficult to review, but provides more information with which to judge the performance level of a system element.

B. Performance

The elements of conducting an effective Radiation Protection Program assessment are:

- Overall plan (annual)
- Establish weekly, daily, breakdown
- Actually write a plan (modify later)
- Preparations-obtain material
- Use protocol for entry, conduct, exit
- Keep contact informed/no surprises

C. Report

Documentation of the findings and observations (note taking) in the field will involve some combination of the following:

- Record book
- 3 x 5 cards
- Actual times, logistics

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- What, when, who, why, where, how
- Documents reviewed
- Interviews

Then comes the time to start to put the report together, whether a weekly report or the inspection report of some other type. The following are suggested:

- Distill as information is gathered, while memory fresh
- Start draft report early

D. Post-assessment actions

- Evaluate assessment responses
- Establish corrective actions and due dates
- Track the status of open action items
- Perform follow-up assessments as necessary

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I. Introduction

II. Field exercise guidelines

A. Briefing for field exercise

The field instructors have prepared to take their participants to the field. They have visited the facility and areas for review, and have compiled information for their participants to use in preparation for the field exercise.

B. Preparations to go to field

A tendency exists to identify surface issues and seek correction of the many items found while walking through the facility. It is vital that personnel who assess be able to sort the issues noted and categorize them so effective use of resources can be made. In other words, identification of symptoms leads to contractors working on the symptoms and not on the underlying, substantive problems.

It can be extremely damaging if we (as overseers, facility representatives, auditors, or assessors) violate the high standards of performance and rules that are being assessed.

Personal safety and facility safety are first and foremost.

C. Findings

Each person will make a presentation to the group. The team leaders will introduce the group, tell where you went, and introduce each presenter. Each person should take no more that one and one-half minutes for the presentation of a finding. Some of the "cats and dogs," or other findings and observations, will be covered at the end of the individual findings.

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The Lead Field Instructor will monitor the overall presentation and comment as appropriate.

We hope to see presentations in this form:

1. List the requirement.

2. State what was observed.

3. State the concern.

I. Summary

(Insert individualized summary.)

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